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Alternate Patterns of Ventricular Activation during Supraventricular Bigeminy

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Summary: Several investigators have previously noted that in the presence of bigeminal atrial extrasystoles, the premature beats may exhibit an alternate pattern of ventricular excitation either in the form of alternating left and right bundle-branch block, or alternating right bundle-branch block and normal intraventricular conduction. However, the association of alternating intraventricular conduction with other types of supraventricular bigeminy has rarely been documented. In this report we present five diverse forms of supraventricular bigeminy exhibiting the phenomenon of alternating ventricular excitation on the early beats. Our findings suggest that the exact mechanism of supraventricular bigeminy is irrelevant in terms of subsequent ventricular events. Practically any type of supraventricular bigeminy may result in an alternate pattern of ventricular activation.

Key words: bigeminy, aberrant conduction, functional bundle-branch block, concealed conduction, refractory period

Introduction

Aberrant conduction of premature atrial complexes (PACs), a frequent phenomenon, occurs whenever atrial extrasystoles encounter conduction delay or block from refractory tissues in parts of the His-Purkinje system. When spontaneous or induced PACs appear in bigeminy, an alternate pattern of ventricular excitation is occasionally seen.[1–5] In this report we present several examples to illustrate that alternate aberration is not limited to bigeminal PACs, but may be present in practically any type of supraventricular bigeminy.

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Case Reports

The electrocardiogram (ECG) in Figure 1 shows sinus rhythm with bigeminal PACs. Large circles indicate timing of the sinus P waves, whereas small circles denote the PACs. The sinus rate is regular, and coupling intervals of all PACs are constant at 0.46 s. Every second PAC is associated with a PR interval of 0.14 s and right bundle-branch block. Alternate PACs conduct with PR intervals of 0.18 s and left bundle-branch block. This is a typical and classic case of alternating left and right bundle-branch block aberration during spontaneous bigeminal atrial extrasystoles.[4,5]

Spacing and morphology of the P waves in Figure 2 are consistent with the diagnosis of "sinus bigeminy." The contours of all P waves are identical and suggest a sinus origin; the P-P intervals, however, alternate between 0.64 and 0.58 s. Sinus bigeminy may result from bigeminal sinus nodal extrasystoles or from 3:2 sinoatrial exit block. Irrespective of the underlying cause of sinus bigeminy, of note is the fact that every second early beat conducts with right bundle-branch block (asterisks), whereas the early beats in between show normal intraventricular conduction (arrowheads). This pattern is consistently present throughout the long continuous tracing, without any change in the P wave morphology or PR intervals.

The seemingly chaotic ECG in Figure 3 demonstrates slow atrial flutter at a rate of 230/min and 3:2 atrioventricular (AV) Wenckebach periodicity; 3:2 Wenckebach results in supraventricular bigeminy. During the bigeminal rhythm, every other early beat conducts with complete right bundle-branch block, whereas the early beats in the alternate couplets conduct with only minimal aberration. The enlargement shows that alternation of ventricular activation is present despite the fact that all PR and R-R intervals show an identical sequence within each Wenckebach period.

Figure 4 illustrates a similar case. Here, the underlying rhythm is atrial tachycardia at a rate of 207/min. In panel A (baseline), there is a type I second-degree AV block with Wenckebach periods of variable duration. In panels B and C (after digoxin), the conduction ratios decreased to 3:2 and 2:1, respectively. During 3:2 Wenckebach (Fig. 4B), again there is a bigeminal spacing of the QRS complexes. The morphology of the early beats within each couplet alternates between right bundle-branch block (asterisks) and an almost normal intraventricular conduction (arrowheads). In Figure 4A, there are longer Wenckebach periods interrupted by pauses ("group beating"). Note that each group starts with a narrow beat after

FIG. 1 Alternating right and left bundle-branch block aberrancy during bigeminal premature atrial contractions (PACs). Large and small circles mark timing of the P waves on sinus beats and the PACs, respectively.

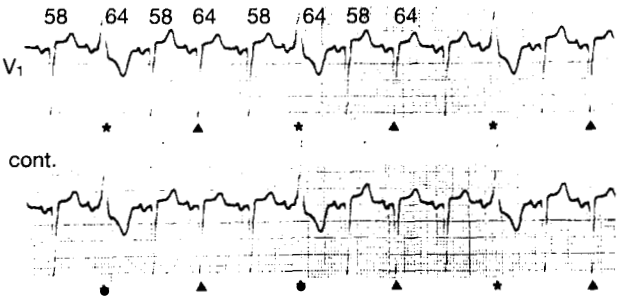

FIG. 2 Sinus bigeminy associated with right bundle-branch block (asterisks) and normal intraventricular conduction (arrowheads) on alternate early beats. Continuous recording. Numbers denote P-P intervals in 1/100 s.

the pause. Thereafter, the first early beats alternately conduct with right bundle-branch block (asterisks) or normal intraventricular conduction (arrowheads). All subsequent beats within each group follow the intraventricular conduction pattern of the initial early beat. Thus, this is an example of alternate pattern of ventricular excitation of entire groups of supraventricular beats during AV Wenckebach periodicity. After achieving stable 2:1 AV block and a regular ventricular rate (Fig. 4C), aberrant intraventricular conduction is no longer present.

Figure 5 shows an accelerated AV junctional rhythm with retrograde P waves (P') and ventricular echo beats. The ventricular echoes show alternating left and right bundle-branch block aberration. The PR intervals on the left bundle-branch block beats measure 0.32 s, whereas the PR interval on the right bundle-branch block beat is shorter at 0.24 s.

Discussion

This report demonstrates that alternate patterns of ventricular excitation can be found in a wide variety of supraventricular rhythms all having only one thing in common, and that is bigeminy. Alternate aberrancy may take the form of alternating left and right bundle-branch block, or alternating right bundle-branch block and normal intraventricular conduction. Since functional bundle-branch block most frequently affects the right bundle branch, other forms of alternate activation patterns are probably quite rare. The etiology of supraventricular bigeminy can be diverse including bigeminal PACs, sinus bigeminy, atrial tachycardia and flutter with 3:2 AV conduction, or accelerated AV junctional escape rhythm with bigeminal ventricular echo beats ("escape-capture bigeminy") (Figs. 1–5). Other forms of supraventricular bigeminy are probably also associated with alternate ventricular activation. In terms of ventricular alternation, the exact cause of supraventricular bigeminy is irrelevant.

Alternate patterns of bundle-branch aberrancy associated with spontaneous or electrically induced bigeminal PACs have been described by Cohen *et al.*,[1] Zipes,[2] Pick and Langendorf,[3] and others.[4, 5] The earliest illustration of this phenomenon probably dates back to Sir Thomas Lewis's classical publication from 1910 (Ref. 6, Fig. 17).[6] Zipes has described a case of atrial tachycardia with 3:2 AV block re-

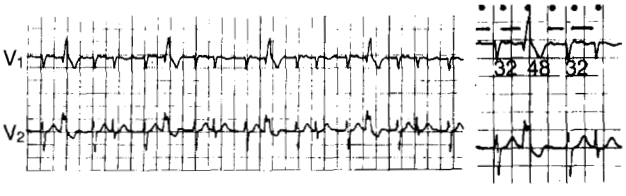

FIG. 3 Slow atrial flutter associated with 3:2 atrioventricular conduction resulting in supraventricular bigeminy. The second beats within each pair alternate between complete right bundle-branch block and minimal aberrancy. In the enlargement, circles denote timing of the flutter waves; horizontal lines illustrate the progressive prolongation of the P-R intervals in each cycle; the numbers indicate the R-R intervals in 1/100 s.

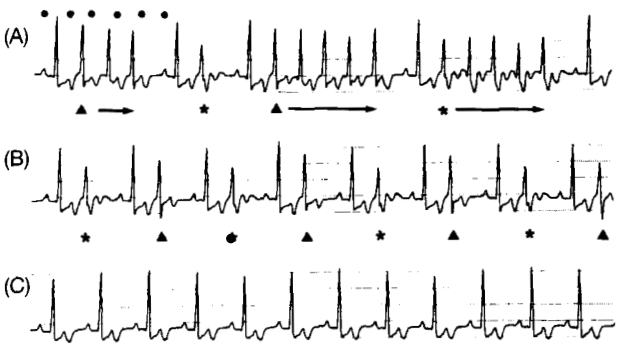

FIG. 4 Atrial tachycardia with variable block (lead I). In Panel B, the conduction ratio is 3:2 resulting in supraventricular bigeminy. Alternate early beats conduct with right bundle-branch block (asterisks) or a more normal intraventricular conduction (arrowheads). In Panel A (before digoxin), there are Wenckebach periods of various duration resulting in group beating. Starting from the second beat within each period, every other group conducts with right bundle-branch block (asterisks); alternate groups show normal intraventricular conduction (arrowheads). During 2:1 block (Panel C), functional right bundle-branch block is no longer present.

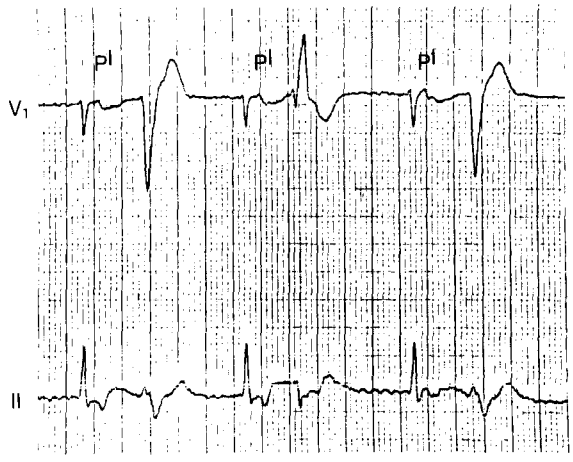

FIG. 5 Accelerated atrioventricular junctional rhythm with retrograde P waves (P') and ventricular echo beats resulting in supraventricular bigeminy. Intraventricular conduction on the echo beats alternates between left and right bundle-branch block.

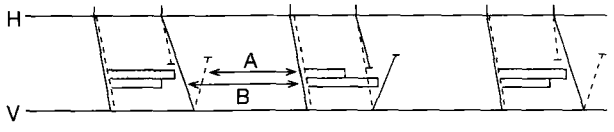

FIG. 6 Ladder diagram illustrating the most likely mechanism of alternating bundle-branch block aberrancy during supraventricular bigeminy. Broken lines represent anterograde and retrograde conduction over the right bundle branch. Shaded bars indicate the refractory periods of the right bundle. Continuous lines and empty bars indicate left bundle branch conduction and refractoriness, respectively. H = activation at the level of the His bundle, V = ventricular activation, A = activation interval of the right bundle branch prior to the second sinus beat, B = activation interval of the left bundle branch prior to the second sinus beat. See text for details.

sulting in alternating aberration.[2] To our knowledge, other forms of supraventricular bigeminy associated with alternating ventricular activation have not been previously reported.

The most widely accepted explanation of alternating aberration during supraventricular bigeminy involves the following electrophysiologic principles: [2,4,5] (1) Cycle length-dependent nature of refractory periods within the His-Purkinje system, and (2) concealed intraventricular reentry (concealed bundle-branch reentry).[7] The ladder diagram in Figure 6 illustrates these concepts. Broken lines represent anterograde and retrograde conduction over the right bundle branch; shaded bars represent the refractory periods of the right bundle. Continuous lines and empty bars indicate left bundle-branch conduction and refractoriness, respectively. The first premature impulse, because of the longer refractory period of the right bundle, conducts with right bundle-branch block, that is, exclusively over the left bundle branch. At the ventricular level, it then retrogradely invades and discharges the right bundle. Activation interval of the right bundle prior to the next sinus beat, therefore, is foreshortened (A) resulting in a now shorter right bundle-branch refractoriness (indicated by the shorter cross-hatched bar on the second sinus beat). Activation interval of the left bundle, on the other hand, was longer (B), hence the longer left bundle-branch refractoriness indicated by the longer open bar following the second sinus beat. The second premature impulse will now conduct with left bundle-branch block, reenter the left bundle from below, and reset the cycle in the other direction.

As indicated in the ladder diagram, alternation of functional bundle-branch block may occur whenever there is bigeminal activation at the level of the His bundle. The atrial mechanism resulting in His bundle bigeminy is irrelevant in terms of subsequent ventricular events. Obviously, an alternate pattern of ventricular activation occurs only if, in addition to supraventricular bigeminy, the coupling intervals of the early impulses, the refractory periods of the bundle branches, and the anterograde and retrograde conduction times within the bundles all have an ideal, critical constellation.

A slightly different explanation also invokes alternating changes in the refractory periods of the bundle branches, but it assumes that unequal activation intervals at the distal levels are due to alternate differences in timing of anterograde rather than retrograde impulses.[1,4] Perpetuation of functional bundle-branch block on consecutively conducted impulses as illustrated in Figure 4A favors concealed intraventricular reentry rather than a simple anterograde delay in bundle-branch conduction.[2]

Conclusion

Alternate patterns of ventricular excitation may occur in any type of supraventricular bigeminy. It is a physiologic phenomenon related to the combination of rate dependency of bundle-branch refractoriness and anterograde delay or concealed retrograde penetration of aberrantly conducted beats into their own blocking zone. In our experience, the sometimes complex electrocardiographic picture is frequently mistaken for polymorphic premature ventricular contractions and may be inappropriately treated for such.

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